



Landsat Provides Global View of Speed of Ice

Kate Ramsayer

Glaciers and ice sheets move in unique and sometimes surprising patterns, as illustrated by satellite-based technology that maps the speed of flowing ice in Greenland, Antarctica, and mountain ranges around the world.

With imagery and data from Landsat 8 scientists are providing a near-real-time view of every large glacier and ice sheet on Earth. The NASA-funded Global Land Ice Velocity Extraction project, called GoLIVE, is a collaboration between scientists from the University of Colorado, the University of Alaska, and NASA's Jet Propulsion Laboratory in Pasadena, California. It uses Landsat 8 imagery to better understand how ice flow is changing worldwide—and how this change impacts sea level.

"We are now able to map how the skin of ice is moving," said Ted Scambos, senior research scientist at the National Snow and Ice Data Center at the University of Colorado Boulder and the Colorado lead for the GoLIVE project. When he and his colleagues first shared these results at the 2016 American Geophysical Union's Fall Meeting in San Francisco, Scambos remarked "From now on, we're going to be able to track all of the different types of changes in glaciers—there's so much science to extract from the data."

With a near-real-time view of how glaciers and ice sheets are moving, researchers can integrate information

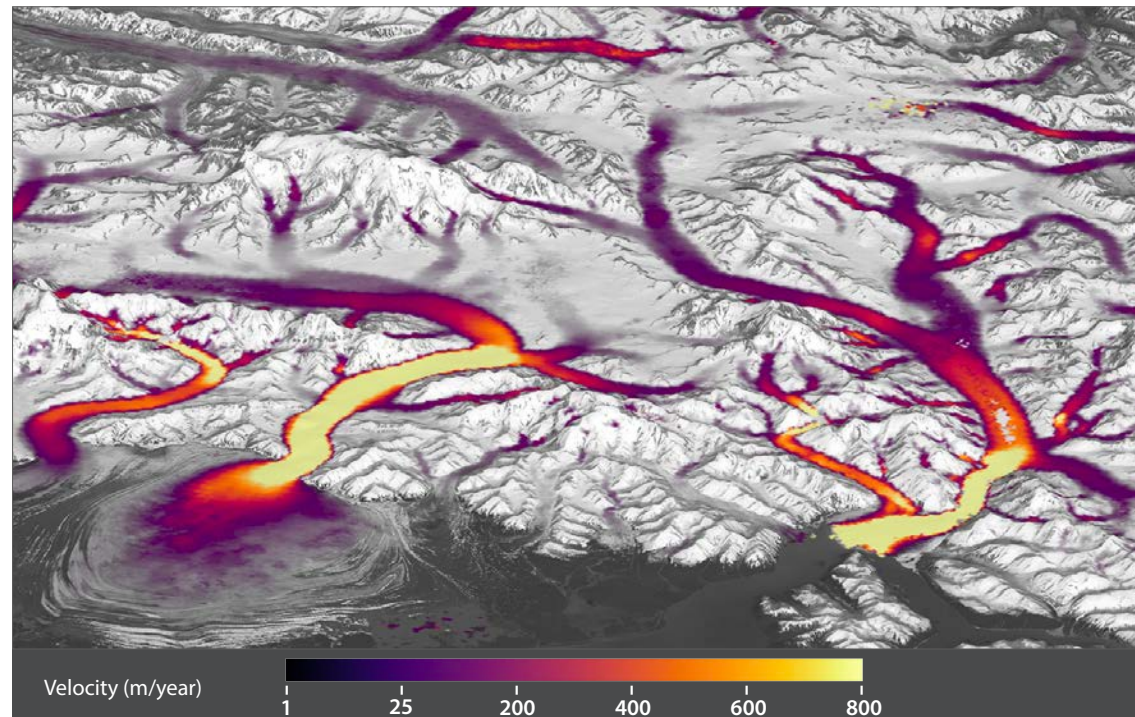
about atmosphere and ocean conditions to determine what causes these ice sheets to change—and what that change means for how much ice is flowing into the ocean. That could help provide critical information to coastal communities that could be most impacted by rising oceans.

"We can use the method to identify which areas to keep an eye on, or which events might lead to a rapid change," Scambos said.

To map the ice, the GoLIVE team has written software that is able to follow the surface's subtle features, like bumps or a dune-like pattern, as they flow toward the ocean. The Landsat 8 satellite collects

images of Earth's entire surface every 16 days. By comparing images taken from the same location, but at different times, the researchers use their software to track the features and determine the speed of the flowing ice.

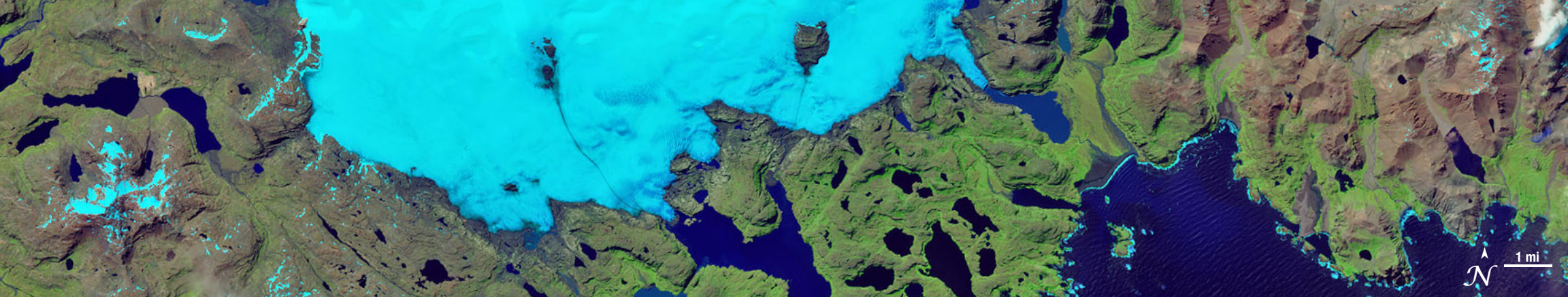
Several new capabilities of Landsat 8 enable researchers to generate these global maps. The satellite can take 700 images a day—far more than its predecessors—which means it captures nearly every scene over land, every day, in all the sunlit parts of its orbit. Previous Landsat satellites often did not have the capacity to collect frequent data over remote sites like Antarctica. ▶



Above: The terminus of Exit Glacier in Alaska's Kenai Fjords National Park. Photo credit: I-pic, Fotolia images

In-page: A map of ice velocity in southeastern Alaska based on GoLIVE data and showing both the Malaspina and Hubbard glaciers. Image credit: Joshua Stevens, NASA Earth Observatory using Landsat-derived ice velocity data courtesy of Alex Gardner, NASA Jet Propulsion Laboratory/California Institute of Technology and ASTER data

Opposite: A rock outcropping along the Fleming Glacier on the west Antarctic Peninsula that feeds the accelerating glaciers in Marguerite Bay. Photo credit: NASA, Operation Ice Bridge



Above: A Landsat 8 image of glaciers extending from Cook Ice Cap that tops Grande Terre Island in the Kerguelen Archipelago. Image credit: Joshua Stevens, NASA Earth Observatory

The imaging system on Landsat 8 is also far more sensitive than past Landsat sensors, allowing it to distinguish far more subtle differences in shading and surface texture. This improved sensitivity, increased frequency of data collection, plus faster and more precise software, has revolutionized the extent to which ice flow speed can be mapped. These features will be continued in the Landsat 9 satellite, scheduled for launch in 2020.

Alaska

In Alaska, researchers can observe surging glaciers in almost real time, according to scientist Mark Fahnestock of the University of Alaska, Fairbanks. Often glaciers in Alaska and the Yukon in Canada are so remote that speedup events can go unnoticed for months, until a pilot flying over the region reports disrupted ice, he explained.

“By measuring ice flow all the time, we can identify a surge as it starts, providing an entirely new way to follow this phenomenon,” he said. “We can also follow large seasonal swings in tidewater glaciers, as they respond to their environment. Scientists need to see all of this variability in order to identify trends that we need to worry about.” The speed of the glacier,

combined with other information such as elevation change from NASA’s Operation IceBridge campaign and other sources, provide researchers in Alaska with a better sense of the entire picture of changing ice.

Greenland

Twila Moon, another research scientist at the National Snow and Ice Data Center uses the global maps to expand the research she does on Greenland glaciers. With the new database, she can study the movements of more than 240 glaciers, which comprise nearly all of the outlets from the ice sheet. Several glaciers in northwest Greenland have accelerated speed in the last few years, while some glaciers in the southeast experienced a large jump in speed, followed by a plateau.

With Landsat 8 making a pass every 16 days, Moon can also measure seasonal changes. Most glacial movement occurs in cyclical patterns throughout the year, but movement patterns may vary. While most glaciers speed up in the warmer summer months, Moon has found several that slow down dramatically in the mid-to-late-summer. The Heimdal Glacier in southeast Greenland, for example, can move more than 10 meters per day (33 feet per day) in early summer, then drop

to less than 6 meters per day (20 feet per day) by August or September. “We can group these glaciers by looking at the similarities in their behavior,” Moon said. “It’s providing an opportunity to get at the underlying drivers of why they change.”

With measurements of what seasonal shifts do to glacier speed, scientists can extrapolate what will happen to those glaciers as global temperatures continue to climb, she explained. With fast-moving Greenland glaciers ending in the ocean, these studies can help scientists estimate how much new ice and water enters the Arctic Ocean. That new water can have both global and local impacts, including changing the local ecosystems, ocean flow patterns, and raising sea level.

“We’re approaching a point where we have enough detailed information at different locations that we can start to answer important questions about what makes glaciers tick,” Moon said.

Antarctica

Tracking the changes in speed in Antarctica is key because of the sheer size of the ice sheet and its potential to contribute to future changes in sea level. Almost 2,000 cubic kilometers (480 cubic miles) of ice flows into the surrounding ocean each year. ▶

Alex Gardner, a research scientist at NASA's Jet Propulsion Laboratory (JPL) combines the detailed Antarctic ice cover seen by Landsat 8 with an earlier continental mapping of glacier flow based on radar data. By piecing the data together, he is working to understand decadal changes in ice flow for the entirety of the Antarctic Ice sheet.

"Seemingly small changes in ice speed on some of these very large glaciers can have a real impact," Gardner said. "The question is, how sensitive are these ice sheets to changes in the atmosphere and the ocean? We could wait and see, or we could look to the past to help inform what is most likely to happen in the future."

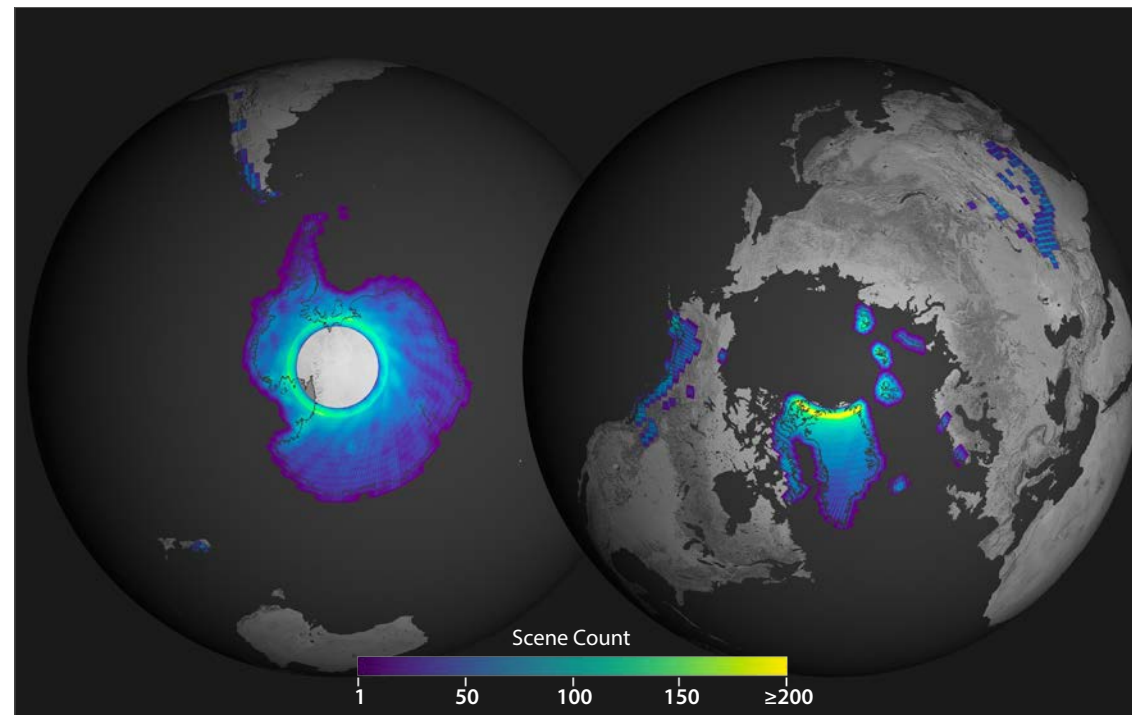
Landsat 8 images combined with those from earlier Landsat satellites reaching back to the 1980s, give researchers decades worth of imagery to investigate these links.

Using Landsat data, Gardner and Catherine Walker, a research scientist at JPL and now at NASA's Goddard Space Flight Center in Greenbelt, Maryland, located Antarctica's fastest accelerating glaciers. They found that between 2008 and 2015, glaciers on the western side of the Antarctic Peninsula dramatically and unexpectedly increased their flow rate after being relatively stable for the prior two decades. This finding helped illustrate how vulnerable the West Antarctic Ice Sheet is to increasing ocean temperatures.

While the ice flow of the West Antarctic Ice sheet accelerated, Gardner and Walker found that flow rates of the East Antarctica Ice Sheet remained remarkably stable during the same period.

More recently, researchers led by Karen Alley from the National Snow and Ice Data Center found that in addition to flow rate, they could also reliably measure how much ice stretches, bends, and

compresses as it flows. This information, known as strain rate, can show where ice is thickening or thinning and can improve predictions of where crevasses may form and how fast calving events will happen. With some modeling, strain rate can even show how firmly the ice is bound to the bedrock below, Scambos explained. ▶



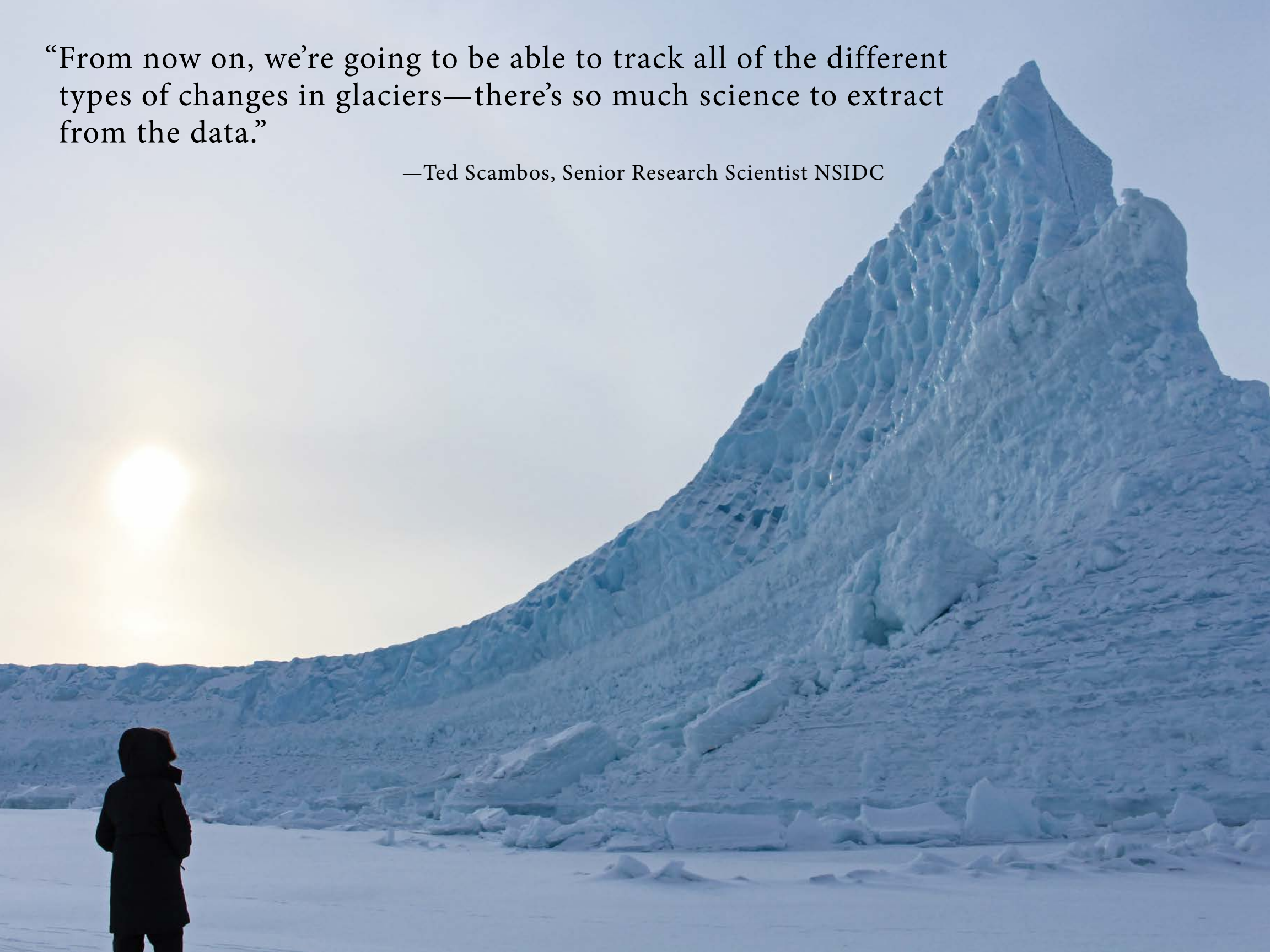
Landsat 8 has a higher imaging capacity than earlier Landsat satellites, so its data archive grows quickly. This image shows all of the cloud-free Landsat 8 images captured over regions of perennial ice cover during 2015. In just one year, some locations had as many as 200 clear observations, while regular cloud cover limited the usable observations in other areas. Image credit: Joshua Stevens, NASA Earth Observatory



Above: A field of crevasses on Antarctica's Pine Island Glacier; close by the glacier transitions from a grounded ice sheet to a floating ice shelf. Photo credit: Ian Joughin, University of Washington

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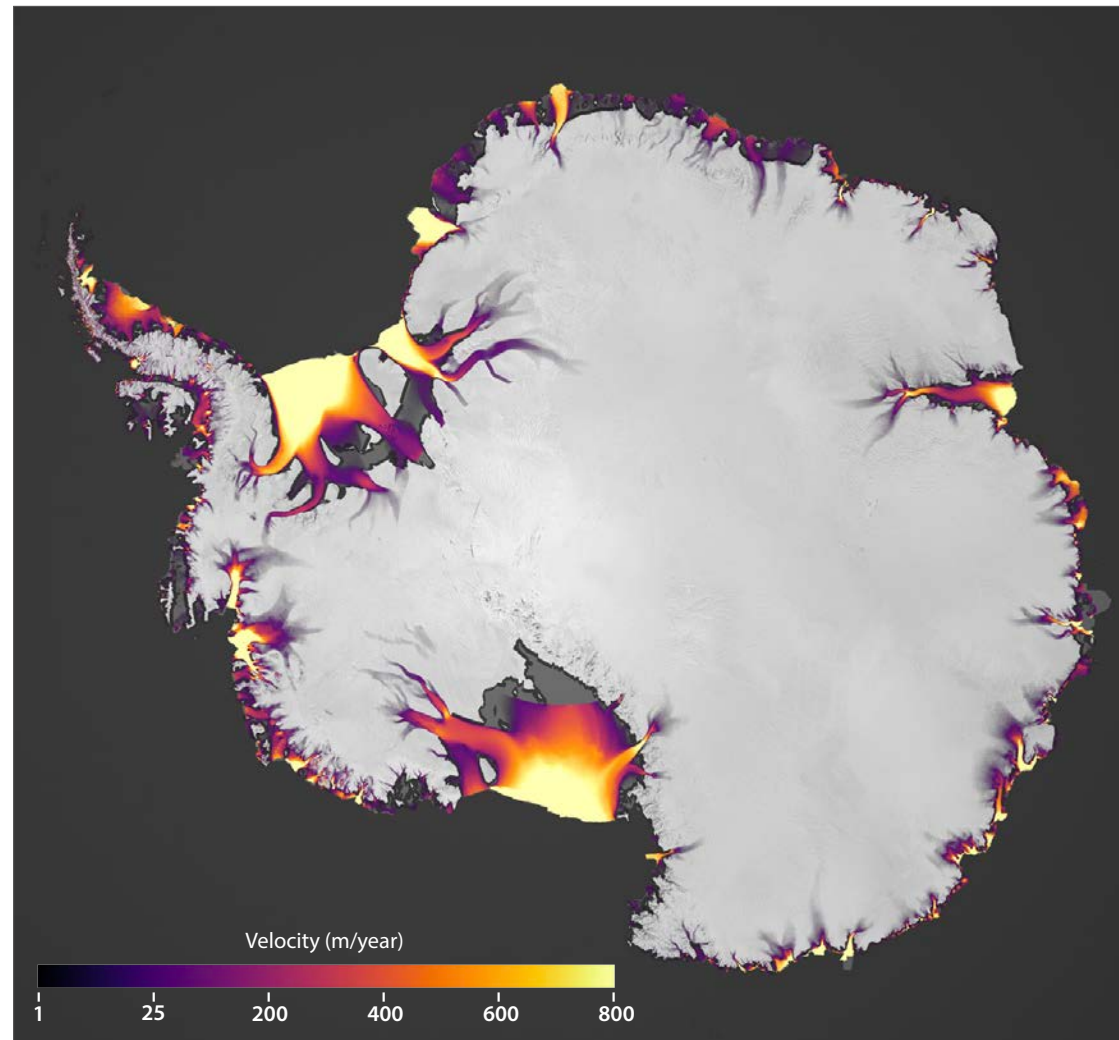
—Ted Scambos, Senior Research Scientist NSIDC



The scope of measurements researchers can make with GoLIVE continues to expand, as does the sophistication of the data processing behind it, allowing better and better monitoring of glaciers around the globe.

“It’s incredible how these seemingly unchanging glacier systems come alive when we look at their changes through time—they’re much more dynamic than you’d think,” Gardner said. ■

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Above: Ice velocity map of Antarctica made with the GoLIVE Landsat-based ice-flow data. Image credit: Joshua Stevens, NASA Earth Observatory

Opposite: A scientist takes in the towering icescapes of Greenland during the 2017 Oceans Melting Greenland field campaign. Photo credit: NASA

Satellite Data Requirements:



16-day revisit , or better



15-30 m resolution



Vis, NIR, SWIR, Panchromatic



Global coverage



Archive continuity and consistency



Rapid delivery of free, unrestricted data



Geolocation ≥ 15 m



Calibration $\geq 5\%$



≥ 12 -bit data digitization